Quiz 5: Wind Energy
MAE 119 Winter 2017
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Closed Book Closed Notes.

Suppose that the wind blows at a particular site at a speed U_1 for a 12 hour period and then for a 12 hour period at a speed $U_{2,}>U_1$. This pattern then repeats. You are asked to evaluate the feasibility of deploying a wind turbine array at this site. The available turbine has a cut-in speed, U_{min} which satisfies $U_{2,}>U_{min} > U_1$ and a cutout speed, U_{max}, that satisfies $U_{max} > U_2$.

a) Plot U(t) over a 24 hour period. What is the average wind speed? 10 points.
b) Label the cut-in and cut-out operational conditions on the plots in (a) and (b) above. 10 points.
c) Plot the power/unit-turbine area, P(t), over a 24 hour period, making sure to indicate the relative value of P(t). 10 points.
d) What is the average power produced, when you average over a 24 hour period? 10 points.
e) What is the capacity factor of a turbine deployed at this site? Remember: capacity factor is the average power produced/peak power capacity. 10 points.

Solution to Quiz 5

March 1, 2017

1 a)

The average wind speed is $U_{\text{ave}} = \frac{1}{2}(U_1 + U_2)$.

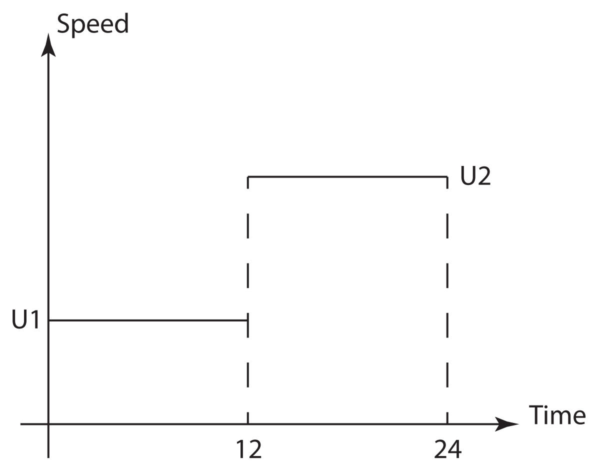

Figure 1: Sketch of $U(t)$.

2 b)

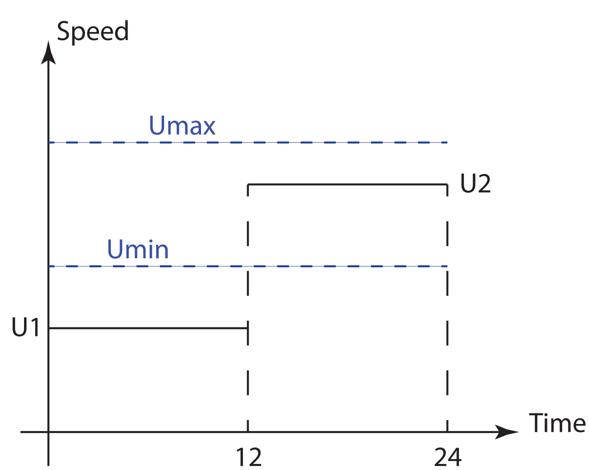

Figure 2: Sketch of $U(t)$ with the label of $U_{\min}$ and $U_{\max}$.

3 c)

The wind turbine only works from $t = 12$ to $t = 24$. The power per unit turbine area labeled in the figure is

$$P/A = \frac{1}{2}\eta\rho U_2^3,$$

where η is the conversion coefficient that has a maximum of $\frac{16}{27}$.

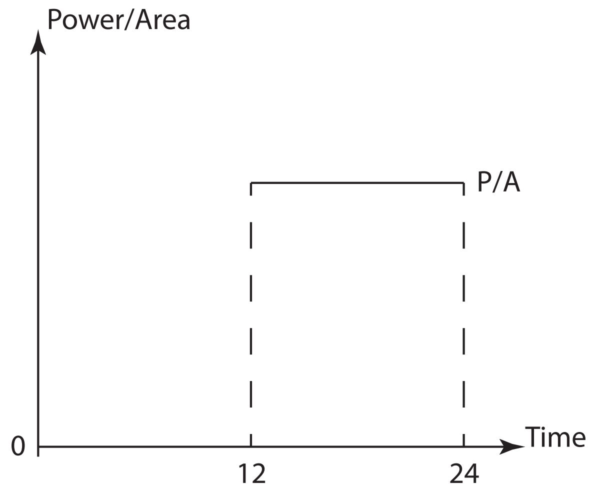

Figure 3: Sketch of $P(t)$.

4 d)

The averaged power per unit turbine area is

$$P_{\text{ave}}/A = \frac{12}{24}P/A = \frac{1}{4}\eta\rho U_2^3.$$

It also fine if the answer of average power is given, i.e.

$$P_{\text{ave}} = \frac{12}{24}P = \frac{1}{4}\eta\rho A U_2^3,$$

where $A = \frac{\pi}{4}d^2$ and d is the diameter of the turbine rotor.

5 e)

$$C_{\text{wp}} = \frac{P_{\text{ave}}}{P_{\text{max}}} = \frac{\frac{1}{4}\eta\rho U_2^3}{\frac{1}{2}\eta\rho U_{\text{max}}^3} = \frac{1}{2}\left(\frac{U_2}{U_{\text{max}}}\right)^3.$$